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Original Article

Fecal Contamination of Drinking-Water in Tanzania's Commercial Capital, Dar Es Salaam: Implication on Health of The Consumers

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Abbreviations CFU: Colony Forming Units; EMA: Environmental Management Act; HWTS: Household Water Treatment and Safe Storage; NEMC: National Environment Management Council; NIMR: National Institute for Medical Research; NTU: Nephelometric Turbidity Unit; OUT: Open University of Tanzania; TBS: Tanzania Bureau of Standards; TDS: Total Dissolved Solids; TZS: Tanzania Standards; WHO: World Health Organization

Abstract

Background: Cholera outbreaks in Tanzania's commercial capital, Dar es Salaam, have been occurring almost each year since 1974 with a Case Fatality Rate (CFR) averaging to 10.5%. This study analyzed major source waters for the city to ascertain safety for human consumption. The objective of the study was to determine the extent to which borehole and tap water meet the recommended drinking water quality standards by domestic and international organizations.

Methods: Total viable and coliform counts were evaluated using the standard plate count method. The physicochemical parameters were analyzed using standard methods.

Results and discussion: With respect to WHO standards, all water samples passed the pH and TDS parameters. With exception of tap water, all borehole water samples failed on turbidity standard maximum of 5 NTU for drinking water. Seven out of eleven (63.6%) borehole water samples and tap water sample failed on microbiological purity of drinking water standards and considered unfit for human consumption as revealed with the presence of unacceptable levels of fecal coliforms.

Conclusion: The implication of these findings is that, large number of Dar es Salaam city dwellers sourcing drinking water from boreholes and tap water are continuously ingesting fecally contaminated water that predispose them to infectious microbial risks of pathogenic gastrointestinal bacteria and viruses. Household based water treatment and safe storage (HWTS) is highly recommended to safeguard health of consumers of water from these sources. Regular assessment of all parameters mentioned in this study is advocated.

Introduction

The relationship between fecal contaminations of drinking water with diarrhea has been addressed in a number of studies [1]. It has already been established that, drinking water is a primary transmission pathway for diarrhea pathogens [2,3]. Unsafe source of drinking water has been significantly associated with an increased risk of diarrhea in a number of studies [1,3]. The risk factors for diarrhea have thus been established to include the consumption of unsafe drinking water, improper waste disposal, incorrect methods of sanitation and inadequate hygiene [4-6]. Drinking water is vital for life to all living organisms. Availability and accessibility to safe drinking water is a basic human right and key in keeping healthy and for the production of safe drinks and food. Water is also of public health importance as it is the medium for the transmission of water related diseases, which constitutes a significant percentage of the burden of diseases that afflict humans [5-7]. Globally, an estimated 1.2 billion people lack access to safe water [6]. In 2010, there were 1.73 billion cases of diarrheal disease globally whereby more than 80% of cases occurred in children under-fives years [8]. Majority of childhood deaths occurs in Sub-Saharan Africa where by 50% of deaths are due to diarrhea [8]. It is estimated that, every 20 seconds, a child dies from a water-related disease [5]. Diarrhea remains the major cause of death among children under five globally [8-9].

Cholera has remained an intriguing problem in Tanzania's commercial capital, Dar es Salaam. Dar-es-Salaam city is one of the areas mostly hit by cholera outbreaks almost in each year [10]. The first 10 cases of cholera in Tanzania caused by *Vibrio cholerae* E1, serotype Ogawa, biotype El Tor were reported in 1974 and since 1977, cases were reported each year with a Case Fatality Rate (CFR) averaging to 10.5% in between 1977 and 1992 [10]. The first major outbreak occurred in 1992 whereby 18,526 cases including 2,173 deaths were reported with CFR11.7%. [10] Another epidemic in 1997 started at the end of January in Dar es Salaam city and accounted for 40,249 cases and 2,231 deaths with CFR 5.54% [10]. In 2006, cholera was reported to have spread in 16 regions between 1st January and 31st December with a total of 14,297 cases and 254 deaths (CFR 1.8%). The region with the highest number of infected patients was the Dar es Salaam city with 8,965 cases representing 62.7% of the total cases and 101 deaths 39.8% of total deaths [10].

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Table 1: Borehole water sample description.

Sampling Number	Sampling Location
Sample 1	Mbagala A
Sample 2	Mbagala B
Sample 3	Mabibo External C
Sample 4	Mabibo External D
Sample 5	Mtongani E
Sample 6	Mtongani F
Sample 7	Mtongani G
Sample 8	Mtongani H
Sample 9	Mtongani I
Sample 10	Mtongani J
Sample 11	NIMR-Mabibo
Dar es Salaam City Tap Water	Mabibo

Groundwater is the major source of daily potable water to an estimated 1.5 billion people worldwide, and it has proved the most reliable and dependable resource for meeting rural water demand in sub-Saharan Africa [11-12]. The quality of groundwater is a function of natural processes as well as anthropogenic activities. Intestines of warm-blooded animals, including humans, harbor pathogens, such as viruses and bacteria and parasites such as round worms. Fecal matter can contaminate water through runoff during rainfall and enter surface water sources. Ground water travels within the surface of the earth through geologic formations or channels, the aquifers. Surface water containing pathogens can enter ground water through cracks in the layers of earth that lead to aquifers. Heavy metals, soluble salt compounds, pesticides and other contaminants that are infiltrating into ground water can also constitute undesirable pollutant when they are not within the recommended levels by the World Health Organization (WHO). *WHO Guidelines for drinking-water quality* provide a basis for the development of national standards that, if properly implemented, ensures the safety of drinking-water. The measures of drinking-water safety are defined in Tanzania by the National Environmental Management Council (NEMC) and the Tanzania Bureau of Standards (TBS) guidelines for drinking water [11-14]. These guidelines are in place to ensure water must be safe for drinking and other household uses.

The former United Nations Secretary-General, Kofi Annan, once insisted that, *"Access to safe water is a fundamental human need and, therefore, a basic human right. Contaminated water jeopardizes both the physical and social health of all people. It is an affront to human dignity."* Good quality drinking water is that which is free from disease-causing pathogens and parasites, unsafe chemical substances and radioactive matter, tastes good, is aesthetically appealing and is free from objectionable color or odor [11-14]. From public health point of view, there is a continued need to ascertain the level of water quality parameters. On this background we carried out this investigation to ascertain the quality of ground water accessed through boreholes to safeguard human health.

Methods

Study design

The study design is a laboratory based analytical study. Water samples were checked for their values in four traits known to be linked to water quality which are pH, hardness, turbidity and microbiological purity.

Study area

The study was carried out in Dar es Salaam city at the Traditional Medicine Research Laboratory in the National Institute for Medical Research (NIMR). Borehole water samples were collected in Mbagala, Mtongani and Mabibo external areas in Dar es Salaam, Tanzania. Tap water samples were collected in Mabibo external.

Sampling

The study was carried out in selected squatter and non-squatter settlement in Dar es Salaam City. A total of eleven boreholes and one tap water source were sampled. The selection of the squatter areas within the city was based on the availability of the boreholes, the frequency of their use and being depended by the large population of the squatter or non-squatter settlement. The squatter areas included Mbagala and Mtongani whereas the non-squatter settlement was the Mabibo external area, all within Dar es Salaam city, Tanzania.

Sample collection

Water samples were collected from eleven different bore hole sampling points in Dar es Salaam city in Tanzania. The average sampling time was 10.00 am each day of sampling. Table 1 shows the description of the sampling areas. The mouth and the outer parts of the borehole taps were sterilized with the flame of a cigarette lighter, and allowed to cool by running the water for about 1 minute before water collection. Each water sample for analysis was collected using a clean one litre plastic container with a screw cap which was thoroughly washed with detergent, soaked with 12% hydrochloric acid and rinsed thoroughly with distilled water. At the point of collection, the container was rinsed three times with the bore whole water sample prior to collection. All of the collected water samples were immediately transported and stored refrigerated at 4°C in the laboratory prior to analysis to avoid microbial action affecting their concentration.

Experimental Methods

Physico-chemical parameters

The physicochemical examination of the water samples was completed within six hours of sample collection. The pH was measured out *in-situ* at the site of sample collection using the Hanna microprocessor pH meter. It was standardized with a buffer solution of pH range between 4 and 9. The turbidity and Total Dissolved Solids (TDS) of the water samples were determined using a Hanna Multi-parameter Water Quality Meter (Hanna instruments, version HI9828).

Bacteriological Examination

Fecal coliform were enumerated by the membrane filtration and commercial field testing DelAgua® kit. The presence of thermo tolerant Escherichia coli in water samples taken from boreholes in different areas in Dar es Salaam city was assessed using Briliance TM *E. coli*/coliform selective medium. Eleven samples of borehole water were assessed and each of the samples represented one borehole water sample which was tested twice. The medium was prepared

Table 2: Physico-chemical parameters of the borehole water samples with comparison to the TBS and WHO limit. values.

Borehole Water Sample	Mean pH	Mean TDS (mg/L)	Mean Turbidity (NTU)
Mbagala A	6.80	5.60	11.30
Mbagala B	6.95	4.30	8.80
Mabibo External C	8.00	7.15	13.85
Mabibo External D	7.05	26.80	53.75
Mtongani E	7.20	5.10	10.20
Mtongani F	6.40	4.50	9.15
Mtongani G	6.50	4.50	9.10
Mtongani H	6.40	11.80	23.75
Mtongani I	6.80	7.20	14.40
Mtongani J	8.01	7.60	15.30
NIMR-Mabibo	7.00	9.50	19.20
Dar es Salaam City Tap Water	7.41	149.86	4.79
Standards			
TBS	6.5 – 9.2	-	5 - 25
WHO	6.5 – 8.0	500	5

by suspending 7g of the Brilliance TM in 250mls of distilled water then boiled gently with agitation to dissolve completely. The solution was cooled to 50°C. 100mls of undiluted sample of water was passed through sterile filter paper. The filter paper was placed in the sterile petri dish containing the coliform selective medium and incubated at 44°C for 24 hours.

Results and Discussion

A summary of the results of the borehole and tap water physicochemical analysis were compared with the World Health Organization (WHO), National Environmental Management Council (NEMC) and the Tanzania Bureau of Standards (TBS) standards and guidelines [12-16]. Overall physicochemical qualities of samples from the 12 different points are as shown in Table 2. The pH of water samples varied significantly ($P < 0.05$) in the 12 sample points which ranged from 6.40 to 8.01. Generally, the pH values obtained for nine samples fall within the World Health Organization (WHO) and ten for the TBS standards for drinking water [12], [14], [16]. One sample deviated from the WHO limit of pH 8.0 whereas two samples showed slight deviations from the minimum with a pH of 6.4. The pH of 8 samples fall within the NEMC and TBS standards range for potable water (pH 6.5 to 9.2).

In Tanzania, a broad pH range from 6.5 to 9.2 is recommended by TBS and NEMC for portable water though on the other hand WHO recommends pH range from 6.5 to 8.0. Scientific studies have also recommended an upper limit at pH 8.0 for effective disinfection and that, as the pH level rises, the disinfecting properties of chlorine declines tremendously at pH 8.5 and there is very little disinfecting power beyond this pH level [14-18]. It has been shown that, at pH values above 8.5, all strains of *E. coli* are more resistant to free chlorine and that, chlorination of water with pH above 8.5 cannot ensure safety of drinking water.

Total dissolved solids (TDS) values of borehole waters are generally below 30mg/l which is within the WHO permissible limit for potable water, this showed that sampled water in the area are quite fresh in most locations [11-14], [16-18].

The turbidity profile varied significantly ($P < 0.05$) and ranged from 8.80 to 53.7 NTU in the sampled borehole waters (Table 2). The turbidity values of water samples were higher than the recommended WHO standard of 5 NTU [11-14], [16-18]. A WHO recommendation on portable water is that, turbidity must at no time exceed 5 NTU [11-14], [16-18]. However, with exception of the Mabibo External D borehole water sample with turbidity of 53.7 NTU, the rest of the values were within the TBS allowable turbidity in between 5 and 25 NTU. Furthermore, the TBS recommended broad range of turbidity in between 5 - 25 NTU for portable water in Tanzania is not supported by the WHO maximum limit of 5 NTU as well as other scientific recommendations for drinking water [11-14], [16-18]. Previous investigation on drinking water quality has led to the development of water turbidity index to determine if the water is 'Good' (< 1 NTU), 'Fair' (1-5 NTU), or 'Poor' (>5 NTU), and provide recommendations for each [11-14], [16-18]. Science has confirmed that as water turbidity increases, the risk to human health also increases particularly for at risk groups such as newborns, the elderly, and people with compromised immune systems such as those with HIV/AIDS, undergoing cancer chemotherapy, or taking organ anti-rejection drugs.

It is well established that; bacteria, viruses, and parasites such as *Giardia* and *Cryptosporidium* can attach themselves to the suspended particles in turbid water. Turbidity then interferes with disinfection by shielding contaminants from the disinfectant such as chlorine [13]. Likewise, enteric viruses and bacteria are inactivated by the maintenance of at least 0.5 mg/liter free chlorine for a minimum of 30 minutes in waters with a turbidity of less than 1 NTU and a pH of less than 8.0 [11-13]. High levels of turbidity (>5 NTU) is a hurdle for disinfection of drinking water as it protects microorganisms from the effects of chlorine, stimulate the growth of bacteria, and give rise to a significant chlorine demand [11-13], [18]. Hence, drinking water with turbidity range in between 5 and 25 NTU does not ensure safety of drinking water.

This study have found majority of boreholes (7 out of 11) and the piped water in Tanzania's commercial capital, Dar es Salaam, are

Table 3: Levels of fecal coliform bacteria in bore-hole water samples.

Borehole place	Colon Forming Units per 100 ml (CFU/100ml)		
	Measured value 1	Measured value 2	Mean
Mbagala A	>50	>50	>50
Mbagala B	3	5	4
Mabibo External C	>50	>50	>50
Mabibo External D	2	1	2
Mtongani E	>50	>50	>50
Mtongani F	>50	>50	>50
Mtongani G	15	10	13
Mtongani H	0	0	0
Mtongani I	0	0	0
Mtongani J	0	0	0
NIMR-Mabibo	0	0	0
Dar es Salaam City Tap Water	5	4	~5
Standards			
TBS (TZS 789:2008): *E. Coli* (fecal coliform) count per 100 ml at 44°C			0
EMA Cap 191, 2007: *E. Coli* (fecal coliform) count per 100 ml at 44°C			0
WHO (2007): *E. Coli* (fecal coliform) count per 100 ml at 44°C			0

contaminated with bacteria found in human and/or animal feces. The microbiological quality analysis of the water samples indicated *E. coli* was absent in only 4 (33.3%) and present in 8 (66.7%) of borehole and tap water samples studied as shown in Table 3. The level of contamination with thermotolerant *E. coli* revealed in this study ranged from the mean of 2 to more than 50 Colony Forming Units (CFU). *E. coli* are bacteria that are naturally present in the environment and used as an indicator that other, potentially harmful, bacteria may be present [12-13].

The presence of *E. coli* indicates that water may be contaminated by human and/or animal excreta. Potentially harmful bacteria in contaminated water can cause short term effects, such as diarrhea, cramps, nausea, headaches, or other symptoms. They may pose a special health risk for infants, young children, and people with severely compromised immune systems. High growth of thermotolerant *E. coli* bacteria in borehole water samples revealed in this study may indicate a higher risk of disease causing pathogens being present in the water. Waterborne pathogenic diseases including skin infections, ear infections, cholera, dysentery, typhoid fever, viral and bacterial gastroenteritis and hepatitis A are contracted through contaminated water [11-13]. The major sanitation facilities in the sampled areas are the pit latrines and septic tanks which are well known for their fecal contamination potential of the ground water resource [12-15]. Leachates containing fecal pathogens from pit latrines and septic tanks can enter groundwater through cracks in the layers of earth that lead to aquifers [12-15].

Thermotolerant *E. coli* found in the borehole water samples is a warning sign of potential health problems that might occur through drinking untreated water from these sources. According to the National Environmental Management Council (NEMC) and the Tanzania Bureau of Standards (TBS), there is no allowable level of fecal coliform in drinking water, hence must be zero [11-16]. Similarly, according to WHO there is no tolerable lower limit for pathogens in water intended for human consumption, for preparing food and drinks, or for personal hygiene hence such water should thus contain no agents pathogenic to humans [11-13].

Disease pathogens in contaminated drinking water sources can usually be stopped and/or killed through the use household water treatment and safe storage (HWTS) and hand washing with soap. HWTS methods such as boiling, chlorination, flocculant/disinfectant powder, solar disinfection, and ceramic filtration have been shown to improve household water microbiological quality or reduce diarrheal disease [13], [17-18].

Conclusion

In conclusion, the results of this study demonstrate that, the piped drinking water in Tanzania's commercial capital, Dar es Salaam, is unfit for human consumption, due to fecal contamination above the maximum permissible limits of TBS, NEMC and WHO. Furthermore, the large majority of boreholes, (63.6%) also had fecal thermotolerant above the maximum permissible limits of TBS, NEMC and WHO standards and it can again be concluded that the water is unfit for human consumption. This study constitutes one of the main public health problems of piped and borehole water supply in Dar es Salaam city, because of the potential effects of fecal thermo tolerant on health. Tanzania and other countries with guidelines that allow broad and extensive range of drinking water parameters, they need to harmonize with WHO guidelines to most effectively protect public health from waterborne and water-related diseases. It is advisable to recall that the most effective means to reduce the health risk from unsafe water remains the households based water treatment and safe storage (HWTS). These findings highlight the necessity of preventive measures such as HWTS, sanitary monitoring to improve sanitary conditions and health education of the population.

Ethical Approval

The research protocol was approved by the Faculty of Science, Technology and Environmental Studies of the Open University of Tanzania, P.O. Box 23409, Dar es Salaam, Tanzania.

Author's Contributions

CSMK: Conceived and designed the study, developed the methodology, collected study samples, carried-out the analysis and interpretation of data, drafted and prepared the manuscript. LY, JAS & HMM: Participated in the design of the study, assisted in carrying out the analysis and interpretation of data, helped to develop the methodology, and provided feedback on the manuscript. All authors have read and approved the final manuscript.

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